**Elaborate: Keep it Cool - Temperature Monitoring**

Ceramic shelters were designed to keep Wedge-tailed Shearwater eggs, adults and chicks from getting too hot or too cold. Four design features help maintain the shelters dry and cool.

* Clay building material provides insulation
* Louvers allow for air circulation
* Shield cover reflects sunshine and provides shade
* Light color reflects sunlight

Loggers were placed inside and outside the shelters, and air temperature (in degrees Celsius) was recorded every hour, for several months, between August and December.

|  |  |  |
| --- | --- | --- |
| Temperature logger used to measure air temperature | Control shade structure used to measure ambient temperature outside shelters | Temperature logger inside clay shelter with chick |
|  |  |  |

In this activity, you will use the data from the loggers to determine how effectively the shelters regulate air temperature, by comparing them against the control shade structures. In the following page, the records from two days are provided, August 15, at the start of the chick-rearing period (when chicks are hatching), and November 15, at the end of the chick-rearing period (when chicks are fledging). Hour “0” is 12:00 A.M., and hour “23” is 11:00 P.M.

The loggers record air temperature every hour. Data are provided for two different nesting sites. Every student will choose one nest site (#1 or #2) to analyze in this activity, and will collaborate with other students to obtain the entire dataset for a comparison of both nest sites.

Two sites and two dates are provided, so students can compare seasonal variability (Aug. versus Nov.) with within-season variability (between two replicate sites).

1. To visualize the data, you plot the hourly temperature data points of **either** Nesting Site #1 **or** Nesting site #2 and its respective control (Control#1 or Control #2) on both dates (Aug 15 and Nov 15). You will have four lines total. Use different colors or hatching for each line, so you can tell which ones are from the ceramic nests and which ones are from the controls, and which ones are from August 15 and November 15. Note: Include a legend to define your coding system, and add a title for your plot.





1. Next, you will calculate the difference between the hourly temperature of the ceramic shelter and its control, for each hour of the day. These values may be positive (shelter is warmer) or negative (control is warmer). To visualize the data better, you can color the cells: positive values in red and negative values in blue. Use the two data tables above, and enter the difference of the temperature values in the spaces provided.

These are the August data and the calculations:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **15-Aug** |  |  |  |  |  |  |
| **Hour** | **Nest#1** | **Control#1** | **Nest1 - Control1** | **Nest#2** | **Control#2** | **Nest2 - Control2** |
| 0 | 25.5 | 25.9 | -0.4 | 25.3 | 25.8 | -0.5 |
| 1 | 25.8 | 26 | -0.2 | 25.4 | 25.9 | -0.5 |
| 2 | 25.7 | 25.9 | -0.2 | 25.5 | 25.9 | -0.4 |
| 3 | 25.4 | 25.6 | -0.2 | 25.6 | 25.6 | 0 |
| 4 | 25.5 | 25.6 | -0.1 | 25.5 | 25.6 | -0.1 |
| 5 | 25.3 | 25.5 | -0.2 | 25.3 | 25.5 | -0.2 |
| 6 | 25.3 | 25.5 | -0.2 | 25.3 | 25.4 | -0.1 |
| 7 | 26 | 26.2 | -0.2 | 25.8 | 26.1 | -0.3 |
| 8 | 27 | 27.2 | -0.2 | 26.8 | 27.1 | -0.3 |
| 9 | 28.3 | 28.5 | -0.2 | 28.1 | 28.5 | -0.4 |
| 10 | 29.2 | 29.6 | -0.4 | 29.5 | 29.9 | -0.4 |
| 11 | 29.5 | 30.1 | -0.6 | 30.3 | 30.7 | -0.4 |
| 12 | 29.7 | 30.3 | -0.6 | 30.6 | 31 | -0.4 |
| 13 | 29.5 | 30 | -0.5 | 30.1 | 30.3 | -0.2 |
| 14 | 28.8 | 29.4 | -0.6 | 29.5 | 29.6 | -0.1 |
| 15 | 28.1 | 28.8 | -0.7 | 28.8 | 28.9 | -0.1 |
| 16 | 28 | 28.3 | -0.3 | 28.2 | 28.4 | -0.2 |
| 17 | 27.9 | 28 | -0.1 | 28 | 28.1 | -0.1 |
| 18 | 27.4 | 27.5 | -0.1 | 27.3 | 27.5 | -0.2 |
| 19 | 26.7 | 26.9 | -0.2 | 26.8 | 27 | -0.2 |
| 20 | 26.5 | 26.7 | -0.2 | 26.6 | 26.7 | -0.1 |
| 21 | 26.1 | 26.3 | -0.2 | 26.3 | 26.4 | -0.1 |
| 22 | 26 | 26.1 | -0.1 | 26.1 | 26.2 | -0.1 |
| 23 | 25.7 | 25.9 | -0.2 | 25.8 | 25.9 | -0.1 |

These are the November data and the calculations:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **15-Nov** |  |  |  |  |  |  |
| **Hour** | **Nest#1** | **Control#1** | **Nest1 - Control1** | **Nest#2** | **Control#2** | **Nest2 - Control2** |
| 0 | 23.3 | 23.7 | -0.4 | 23.7 | 23.3 | 0.4 |
| 1 | 23.2 | 23.5 | -0.3 | 23.5 | 23 | 0.5 |
| 2 | 23 | 23.2 | -0.2 | 23.2 | 22.7 | 0.5 |
| 3 | 22.1 | 22.8 | -0.7 | 22.8 | 22.3 | 0.5 |
| 4 | 22 | 22.6 | -0.6 | 22.6 | 22.2 | 0.4 |
| 5 | 21.9 | 22.7 | -0.8 | 22.7 | 22.4 | 0.3 |
| 6 | 22 | 22.7 | -0.7 | 22.7 | 22.3 | 0.4 |
| 7 | 22.3 | 23 | -0.7 | 23 | 22.8 | 0.2 |
| 8 | 23.5 | 24.3 | -0.8 | 24.3 | 25 | -0.7 |
| 9 | 26.6 | 26.7 | -0.1 | 26.7 | 27.3 | -0.6 |
| 10 | 27.2 | 27.8 | -0.6 | 27.8 | 28.2 | -0.4 |
| 11 | 27.8 | 28.2 | -0.4 | 28.2 | 28.8 | -0.6 |
| 12 | 28.9 | 28 | 0.9 | 28 | 28.3 | -0.3 |
| 13 | 28.2 | 27.3 | 0.9 | 27.3 | 27.4 | -0.1 |
| 14 | 27.6 | 27 | 0.6 | 27 | 27.1 | -0.1 |
| 15 | 27.7 | 27.1 | 0.6 | 27.1 | 27.1 | 0 |
| 16 | 27.3 | 26.9 | 0.4 | 26.9 | 27 | -0.1 |
| 17 | 26.2 | 26.4 | -0.2 | 26.4 | 26.3 | 0.1 |
| 18 | 25.6 | 25.9 | -0.3 | 25.9 | 25.8 | 0.1 |
| 19 | 25.5 | 25.7 | -0.2 | 25.7 | 25.6 | 0.1 |
| 20 | 25.5 | 25.8 | -0.3 | 25.8 | 25.7 | 0.1 |
| 21 | 25.4 | 25.8 | -0.4 | 25.8 | 25.7 | 0.1 |
| 22 | 25.5 | 25.8 | -0.3 | 25.8 | 25.6 | 0.2 |
| 23 | 25.2 | 25.6 | -0.4 | 25.6 | 25.4 | 0.2 |

1. Next, you will summarize the range of temperature in the ceramic shelter and the control for both August 15 and November 15. Generate two separate plots for each date, showing the average temperature, the minimum temperature, and the maximum temperatures using different symbols. You may also use different colors, so you can tell which data are from real nests and which data are from nearby controls, and so you can tell which ones are from August and November. Note: Include tick mark labels (on the X axis) and a legend on the plot to define your coding system. Add a title for your plot.

These are the calculations for August 15:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **15-Aug** | **Nest#1** | **Control#1** | **Nest#2** | **Control#2** |
| **minimum** | 25.3 | 25.5 | 25.3 | 25.4 |
| **average** | 27.10 | 27.39 | 27.25 | 27.48 |
| **maximum** | 29.7 | 30.3 | 30.6 | 31.0 |



These are the calculations for November 15:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **15-Nov** | **Nest#1** | **Control#1** | **Nest#2** | **Control#2** |
| **minimum** | 21.9 | 22.6 | 22.6 | 22.2 |
| **average** | 25.14 | 25.34 | 25.34 | 25.30 |
| **maximum** | 28.9 | 28.2 | 28.2 | 28.8 |



1. For each nesting site, calculate the difference in the temperature of the nest and the control for every hour. Calculate the Nest Temperature minus the Control Temperature for both August 15 and November 15. This value will be positive when the nest is warmer than the control and negative when the control is warmer than the nest. Then the temperature of the nest and the control are the same, the difference value = 0. Plot these new difference values on a new graph (2 lines in total). Use different colors or symbols for each line, so you can tell which one is from August 15 and which one is from November 15. Because these values can be positive or negative, so set up your y axis accordingly. Note: Include a legend on the plot to define your coding system, and add a title for your plot.

These are the data for August and November:

Note: positive values indicate that the ceramic shelter is warmer than the control and negative values indicate that the control is warmer than the ceramic shelter.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **15-Aug** |  |  | **15-Nov** |  |  |
| **Hour** | **Nest1 - Control1** | **Nest2 - Control2** | **Hour** | **Nest1 - Control1** | **Nest2 - Control2** |
| 0 | -0.4 | -0.5 | 0 | -0.4 | 0.4 |
| 1 | -0.2 | -0.5 | 1 | -0.3 | 0.5 |
| 2 | -0.2 | -0.4 | 2 | -0.2 | 0.5 |
| 3 | -0.2 | 0 | 3 | -0.7 | 0.5 |
| 4 | -0.1 | -0.1 | 4 | -0.6 | 0.4 |
| 5 | -0.2 | -0.2 | 5 | -0.8 | 0.3 |
| 6 | -0.2 | -0.1 | 6 | -0.7 | 0.4 |
| 7 | -0.2 | -0.3 | 7 | -0.7 | 0.2 |
| 8 | -0.2 | -0.3 | 8 | -0.8 | -0.7 |
| 9 | -0.2 | -0.4 | 9 | -0.1 | -0.6 |
| 10 | -0.4 | -0.4 | 10 | -0.6 | -0.4 |
| 11 | -0.6 | -0.4 | 11 | -0.4 | -0.6 |
| 12 | -0.6 | -0.4 | 12 | 0.9 | -0.3 |
| 13 | -0.5 | -0.2 | 13 | 0.9 | -0.1 |
| 14 | -0.6 | -0.1 | 14 | 0.6 | -0.1 |
| 15 | -0.7 | -0.1 | 15 | 0.6 | 0 |
| 16 | -0.3 | -0.2 | 16 | 0.4 | -0.1 |
| 17 | -0.1 | -0.1 | 17 | -0.2 | 0.1 |
| 18 | -0.1 | -0.2 | 18 | -0.3 | 0.1 |
| 19 | -0.2 | -0.2 | 19 | -0.2 | 0.1 |
| 20 | -0.2 | -0.1 | 20 | -0.3 | 0.1 |
| 21 | -0.2 | -0.1 | 21 | -0.4 | 0.1 |
| 22 | -0.1 | -0.1 | 22 | -0.3 | 0.2 |
| 23 | -0.2 | -0.1 | 23 | -0.4 | 0.2 |

These are the calculations for August and November:

Note: positive values indicate that the ceramic shelter is warmer than the control and negative values indicate that the control is warmer than the ceramic shelter.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **15-Aug** | **Nest1 - Control1** | **Nest2 - Control2** | **15-Nov** | **Nest1 - Control1** | **Nest2 - Control2** |
| **minimum** | -0.7 | -0.5 | **minimum** | -0.8 | -0.7 |
| **average** | -0.29 | -0.23 | **average** | -0.21 | 0.05 |
| **maximum** | -0.1 | 0 | **maximum** | 0.9 | 0.5 |



**Discussion Questions:**

1. How does the temperature change inside the shelter throughout the day?

When is the temperature the highest? When is the temperature the lowest?

To answer this question, see the results of figure 1.

The air temperature in the nests is highest in the middle of the day, between 11 A.M. and 1 P.M.

The air temperature in the nests is lowest in the early morning, between 3 A.M. and 6 A.M.

NOTE: in Hawaii, sun comes out around 6 A.M. and sets around 6 P.M.

1. How does temperature change outside the shelter (control shade structure) throughout the day? When is temperature the highest? When is the temperature the lowest?  
   To answer this question, see the results of figure 1.

The air temperature in the control shade structures follows a very similar pattern to what we saw in the nests. The maximum temperature occurs around the middle of the day, and the minimum temperature occurs during the early morning.

1. How does the temperature change inside and outside the shelter from Aug. to Nov.?  
   To answer this question, see the results of figures 2 for August and November.

The air temperature is consistently higher in August than in November.

This seasonal increase is evident in the minimum, the average, and the maximum values.

Otherwise, there is no clear pattern between the ceramic shelter and the control: sometimes one is warmer and other times the other one is warmer.

1. Is the temperature generally warmer or cooler inside the shelter compared to the control?  
   The air temperature is generally cooler in the ceramic shelter, compared with the adjacent control shade structures. This can be seen by the largely negative values, when the hourly values are compared. However, occasionally the ceramic shelters are warmer than the adjacent control shade structures.
2. Why do you think it is important for the birds to have protection from heat? What might happen to eggs, chicks, and adults that get too hot inside of the ceramic shelter?  
   Eggs, chicks and even adults exposed to high temperatures can die. In particular, eggs and chicks can dehydrate and die. Eggs will eventually denature from the heat, like getting cooked. Chicks can become overheated start panting and often walk to the entrance to feel the wind, exposing themselves to predators. Adults that become overheated also start panting and may leave the nest, abandoning the incubating egg, or may stay incubating the egg and die, if the air temperature gets too high in the nest.